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# Illinois. University

Program of education  
and research related  
to air transportation  
at U. of I.



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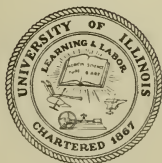
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## A PROGRAM OF EDUCATION AND RESEARCH RELATED TO AIR TRANSPORTATION AT THE UNIVERSITY OF ILLINOIS INCLUDING A UNIVERSITY AIRPORT

Prepared for the  
Board of Trustees of the University  
by Dean M. L. Enger and President A. C. Willard  
April 10, 1942



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AT THE MEETING of the Board of Trustees on January 24, 1942, the President of the University was authorized to request the Governor to include in a call for a special session of the General Assembly of Illinois an appropriation of \$200,000 for the purchase of one section of land for an airport. This request has been made and is now under consideration by the Governor. The President was also authorized to make a survey, in consultation with the College of Engineering and with appropriate State and Federal agencies, and to report a proposal for the operation of such an airport. This report is being submitted, in accordance with that authorization, for consideration by the Board of Trustees.

### Background

The University was established by an act of the legislature creating the Illinois Industrial University in 1867, and was opened in 1868, to serve the needs of the people of the State, through education and research, for the development of agriculture and the mechanic arts. At that time those two important industries were greatly in need of more scientific and technical knowledge than then existed, and above all there was a great lack of institutions of learning in which students could study the applied sciences and related subjects so essential to successful farming, manufacturing, and transportation. The University met this situation as best it could with a courageous and determined faculty devoted to the teaching, discovery, and dissemination of the scientific and technical knowledge so badly needed in those early days.

Since its opening in 1868 the University of Illinois has developed and expanded into numerous colleges, schools, and experiment stations covering many professional fields, until it is now one of the four or five largest universities in the country with an annual enrollment of 15,995 students as of March 1, 1942, and a faculty and staff of 2,838 persons. During its lifetime, it has continued to be the policy of the University to meet so far as possible the demands for new and varied educational and research programs growing out of the rapidly changing social, industrial, and professional life of the state and nation.

### Air Transportation: A Major Industry

The most recent demand for a new program of education and research at the University rests squarely on the amazing growth of air transportation all over the world. The supreme importance of the airplane in war has accelerated research and developments in design, and has caused a vast increase in the manufacture of many types of aircraft, in the training of pilots and ground crews, and in construction of airports. There is every indication that air transport will assume as much importance in the post-war economy as it now assumes in war.

It is hardly conceivable that the University can be completely effective in any program designed to aid and advance military and civil air transportation unless it can acquire a fully equipped modern airport in close proximity to its Urbana-Champaign campus. Such an airport should have a field area of 640 acres, well drained and equipped with paved runways of suitable length, some of which should be wide enough for planes landing by instrument control. In addition, hangars, machine shops, laboratories and other service and administration buildings will be necessary. Many of the various research projects related to air transportation should be housed in appropriate buildings located at the field. This airport must be as modern and complete as science and technology can make it. Its function is to serve a great state in providing education and research at the University of Illinois for the advancement of air transportation in this country.

### **Many Problems Confront the Air Transportation Industry**

The requirements of war have served to emphasize the importance of unsolved physiological and medical problems involving the fundamental problems of circulation, body temperature, special sense acuity, muscular coordination, work capacity, and mental alertness and fatigue. The fighting services are subjected to an extreme range of temperature, humidity, and atmospheric pressure, varying from arctic cold to tropical desert and jungle heat, from atmospheric pressures at sea level to the low pressures and temperatures of high altitude flying. In the overall development of aeronautical educational and research programs the biological sciences have an important place. Researches involving the effect of weather and the atmospheric environment on human beings have been under way in the College of Medicine for a number of years. (See Appendix I for a partial list of publications on "Researches on the Influence of Atmospheric Environment Related to Problems in Aviation Medicine.") These researches, together with those now in progress or being planned, involve the departments of Medicine, Physiology, Physiological Chemistry, Pathology, Pharmacology, Psychology, Psychiatry, and Surgery.

Some important problems of education and research require a regrouping of fields of knowledge and concerted action of specialists in several departments and faculties in the University. The development of the airplane and air transportation is such a problem. Fortunately, the University has such a group of men, both in the medical and engineering fields, who have been cooperating effectively in a research program on the effect of the atmospheric environment.

The University, through the Engineering Experiment Station, has made important contributions to the development of railway and highway transportation. (See Appendix II to this report as evidence of what the University has done for land transportation.) This has been

done through the cooperation of members of the staff and the use of equipment of nearly every department of the College of Engineering and the departments of Chemistry, Chemical Engineering, and Mathematics in the College of Liberal Arts and Sciences. With adjustments and additions to the staff and facilities, the University of Illinois can make contributions to the training of personnel and to the development of air transportation comparable with those which have increased the economy, safety and comfort of railway and highway transportation.

The design of the many types of airplanes for military and civilian service requires, in addition to the fundamental engineering training, instruction and research in aerodynamics, thermodynamics, engines, structural design, fatigue of metals, vibrations, radio, metallurgy, tests and specifications of materials, instruments, etc. This will require modifications (often small) and additions to existing advanced undergraduate and graduate courses in the departments of Mechanical Engineering, Civil Engineering, Theoretical and Applied Mechanics, Electrical Engineering, Metallurgical Engineering, and Physics.

Airport design is in its infancy. Many problems are involved: selection of site, grading, drainage, soil stabilization, paved runways, a comprehensive lighting plan, design of hangars and other buildings, the analysis and treatment of soil, weather bureau, radio facilities, water supply, and sewage disposal. In November 1940 it was reported that there were 2,400 civil airports in the United States, but there were only 36 airports meeting Class 3 specifications of the Civil Aeronautics Administration. Since then many new airports have been built and old airports have been improved. The planning and construction of airports require the cooperation of men trained in Architecture, Civil Engineering, Electrical Engineering, Meteorology, and Agronomy. The agronomist is needed for testing, selecting, and treating the soil and selecting seed for turf outside of the paved landing strips. Grading operations usually expose subsoil on which grasses grow with difficulty. For landings most pilots prefer turf because there is less damage to tires, but pavements are necessary in wet weather and for heavy planes.

Training of inept military pilots is expensive in money, equipment, and time. Investigations are being made to devise simple tests which will eliminate candidates for the air corps who lack the coordination, quick responses, and the ability to act correctly under stress so vitally important for military pilots. Promising results have been obtained. This important work is in the province of Psychology.

The present airport facilities of the United States can be compared with the highway facilities twenty-five years ago. There were then fairly good automobiles, but their use was limited by lack of paved roads. Billions have since been spent for highways. We now have good airplanes, but their use is limited by lack of airports. This is true of the Midwest in general, and of the State of Illinois in particular. In the near future the network of airways will be greatly increased. An

airway from Kansas City to Indianapolis passing through Quincy, Springfield, Decatur, Champaign-Urbana, Danville, and Crawfordsville would serve a large population, as would an airway from Chicago through Kankakee, Champaign-Urbana, Mattoon, Effingham, Mt. Vernon, Carbondale, Cairo, to Memphis. The income from commercial operations of the airport would help defray the cost of operation and maintenance.

### **Flight Training for Civilian, Military, and Naval Personnel**

One of the most important services of a University airport would be to provide flight training for civilian aviation units, as well as for military and naval aviation units. The Civil Aeronautics Administration is continuing and expanding its program of civilian pilot training (C.P.T.) at colleges and universities where suitable, approved flying fields are available. The Navy has a greatly expanded aviation program (known as V-5) for college men, and the Navy recommends that men enlisted in the V-5 aviation cadet program get flying experience while still in college by enrolling in the C.P.T. course at their own universities. An airport at this University would make it possible to establish a Reserve Officers' Training Corps for the Air Corps of the Army. This branch of the service will be very important in the future, and an aviation unit should be included in the University's ROTC brigade.

### **General Requirements for an Airport**

The Civil Aeronautics Administration recommends "to any city, regardless of size, that an area adequate for all future needs, as nearly as can be anticipated, should be controlled from the start of an airport project in order to provide for future expansion." A square mile of land is recommended. Consideration must be given to possible obstructions in the approach areas within two miles of the boundaries of the airport. The towers of the University radio station are over 300 feet high and exclude from consideration all land lying within a two-mile radius.

Engineers of the Civil Aeronautics Administration and the Illinois Aeronautics Commission have made a preliminary inspection of the area in the vicinity of the Twin Cities and have found several promising sites. The site most favored is about four miles from the campus.

A Class 3 Airport is recommended for the University. Such an airport would be adequate for "important cities on feeder line airway systems and many intermediate points on main line airways—general population range 25,000 to several hundred thousand." A Class 3 Airport should have landing strip lengths of at least 3,700 feet at the local elevation above sea level. It would accommodate present day transport planes up to 50,000 pounds gross weight. The facilities required are in general the same as for a Class 4 Airport (except for minimum

runway lengths of 4,600 feet and an administration building) and include: drainage, fencing, marking, wind direction indicator, lighting, hangar and shop, fueling, weather bureau, two-way radio, and visual traffic control. The lighting requirements include: airport beacon, boundary lights, range lights, obstruction lights, illuminated wind cone, apron flood lighting, traffic pistol light, illuminated wind tee, ceiling projector, runway contact lights, and approach lights on every runway equipped for instrument landing. The width of usable landing strips should be 500 feet and runways should have a width of 150 feet (200 feet is required for runways equipped for instrument landings) and should be laid out so that landings can be made within  $22.5^{\circ}$  of the wind direction 90 per cent of the time when wind velocities exceed 4 miles per hour.

### **Proposal for the Acquisition and Operation of a University-Owned Airport**

Since the operation of an airport at the University depends entirely upon the acquisition of a suitable area for a flying field, and its subsequent construction and equipment, the following program of procedure is necessarily involved in providing for such an airport:

1. Purchase of a tract of land, approved by the Civil Aeronautics Administration, from funds provided through an appropriation by the General Assembly of Illinois. Proposed amount, \$200,000.

2. Preparation of plans and specifications for converting this tract into a flying field which will meet the Class 3 requirements of the Civil Aeronautics Administration. Such services have been offered by the Illinois Aeronautics Commission provided the University controls the area to be improved. No funds are required of University of Illinois.

3. Funds for the improvement of the field—grading, drainage, fencing, runways, and airport lighting—may be secured as a 100 per cent grant from the Civil Aeronautics Administration, or as a 75 per cent grant from W.P.A. provided approval of the project can be secured after items 1 and 2 have been completed. It is difficult to estimate the cost of this work before the land has been selected and surveys have been made. However, the probable cost based on similar airports will run about \$800,000. The sponsor's contribution for the W.P.A. grant would then be at least \$200,000.

4. Funds for improvements—hangars, shops, weather bureau, laboratories and equipment—cannot be secured from the Civil Aeronautics Administration, but W.P.A. may approve such a project if labor conditions warrant an allocation of federal funds. However, the amount of W.P.A. allotment which could be used for building construction may be limited by lack of skilled workmen on W.P.A. rolls. At a total cost of \$750,000 it would probably be necessary to secure \$500,000 to \$650,000 from the State of Illinois.

### Recapitulation

The expenditure for a Class 3 airport is estimated to be:

|                                      |                |
|--------------------------------------|----------------|
| Land .....                           | \$ 200,000     |
| Grading, drainage, runways, etc..... | 800,000        |
| Buildings and equipment.....         | <u>750,000</u> |
| Total.....                           | \$1,750,000    |

If the Civil Aeronautics Administration assumes cost of grading, drainage, runways, airport lighting, etc., and W.P.A. contributed to other improvements, the appropriation required from the State of Illinois is estimated to be:

|                              |                             |
|------------------------------|-----------------------------|
| Land.....                    | \$200,000                   |
| Buildings and equipment..... | <u>\$500,000 to 650,000</u> |
| Total.....                   | \$700,000 to \$850,000      |

If the work of grading, drainage, construction of buildings, etc., is done as far as possible under a W.P.A. grant, the State of Illinois would probably have to appropriate the following amounts:

|                              |                             |
|------------------------------|-----------------------------|
| Land .....                   | \$ 200,000                  |
| Grading, etc.....            | 200,000                     |
| Buildings and equipment..... | <u>\$500,000 to 650,000</u> |
| Total.....                   | \$900,000 to \$1,050,000    |

5. The operation of the airport would, of course, involve flying equipment, personnel, supplies, and maintenance. It is recommended that the University operate the airport through a manager reporting to the Professor of Aeronautical Engineering. When it is decided to go ahead with the project a competent man with aeronautical experience and with a professional background of education in this field should be appointed to assist in planning the development of the physical facilities and the curriculum. During the construction period it is recommended that aeronautical options be offered in Mechanical Engineering and Civil Engineering, and since there will be little laboratory work the increase in expense will be small.

The minimum staff at the airport and the salary and wages would probably be:

|                             |              |
|-----------------------------|--------------|
| Manager.....                | \$ 4,000     |
| Two flight instructors..... | 5,000        |
| Two airplane mechanics..... | 4,000        |
| Miscellaneous wages.....    | <u>4,000</u> |
|                             | \$17,000     |

The net income from airport operations should be in excess of the above expenses. If the Civilian Pilot Training Program is continued with quotas of 50, at least seven flight instructors would be required, but the net return would be higher.

When the Department of Aeronautical Engineering is established the salary budget would be about as follows, on the assumption of 100 seniors in the curriculum:

|                               |              |
|-------------------------------|--------------|
| Head of department.....       | \$ 7,500     |
| Two Assistant Professors..... | 7,200        |
| Four Instructors.....         | 9,600        |
| Two mechanics.....            | 4,000        |
| Wages .....                   | <u>1,000</u> |
|                               | \$29,300     |

Against this there would be an offset due to decreased enrollment in other curricula in engineering.

The Expense and Equipment budget for the Department should not exceed \$6,000 for the first year.

## Researches on the Influence of Atmospheric Environment Related to Problems in Aviation Medicine

Flight personnel and passengers are subjected to stresses and conditions of atmospheric environment more severe than those encountered in transportation on the ground. As compared with military aviation, civilian passengers are subjected to a relatively small range of conditions. However, many civilian flyers are in such poor physical condition that even small changes of atmospheric pressures and other stresses have pronounced effects. Investigations in aviation medicine are therefore of importance in all flying. In the full development of instruction and research in air transportation the well-being of the flyer as well as the improvement of equipment must be taken into account.

Many investigations have been carried on by members of the staff of the College of Medicine on the adjustment of human beings to the atmospheric environment. In the last few years there has been cooperation between the Colleges of Medicine and Engineering in planning equipment in which investigations can be made on human subjects under controlled atmospheric pressures, temperatures, and humidities. These investigations are fundamental in aviation medicine. The following bibliography lists representative pertinent publications on work which has been done:

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#### A SUPPLEMENTARY STATEMENT ON PROBLEMS RELATED TO AVIATION, SUBMARINE, AND WAR MEDICINE

By M. K. FAHNESTOCK, Research Associate Professor of Mechanical  
Engineering at the University of Illinois

Since 1937 the University of Illinois has been developing a group research program in its Colleges of Medicine, Agriculture, and Engineering to study the influence of atmospheric environment on humans and animals. The scope of

the program includes studies involving the influence of one or more of the following factors: temperature, humidity, absolute pressure, air motion, ionization, air-borne bacteria, air-borne foreign material, radiation, gas concentrations, sound or noise, light, and possibly factors now unknown. Perhaps the most important and unique aspect of the program is the unprecedented coordination of the personnel and physical facilities of three of the University's Colleges in a common effort.

#### **Studies on the Influence of Atmospheric Environment and the War**

Through contact with the Army, the Navy, and with the Committees on Aviation Medicine and on Medical Research of the Office of Scientific Research and Development, the University is familiar with some of the requirements of war which have accentuated the importance of all atmospheric factors which directly or indirectly affect the performance of man on the sea, in the air, and on land. The implements of modern mechanized warfare, including the airplane, the submarine, and tank, and the use of troops in climates from the Arctic to the Tropics, place untold stresses on the combatants.

##### **a. Aviation Medicine**

A human crew and a mechanical machine are the two units which make a flying weapon of military value. The maximum performance of the weapon is fixed by the ability of the selected crew and the plane to function and to carry out its mission during critical operations. The limitations of the weapon are, therefore, set either by the human crew or by the mechanical machine, or by both. Available information indicates that the human element is probably the limiting factor in regard to most strategic operations, involving altitude, acceleration, and endurance. Therefore, it becomes the responsibility of members of the biological sciences to raise the ceiling of the performance of the military flying weapon by raising the ceiling of performance of the crew. This can only be accomplished by intensive research with animals and humans, in most cases under conditions simulating those encountered in actual military operations. These conditions are those which accompany high altitudes, high accelerations, continuous and discontinuous flight, and mental and physical fatigue.

At an altitude of 40,000 feet the temperature of the air is about minus 67° F. and the absolute pressure is about 5.54" Hg., or 2.71 lb. per sq. in. The density of the air is about one-sixth of that at sea level, and the human cannot exist without a supply of pure oxygen. In ascending at a rate of one mile per minute from an environment with a temperature of possibly 90° F. and a pressure of 29.9" Hg. to an environment with a temperature of minus 67° F. and a pressure of 5.5" Hg., the human organism is subjected to a violent change in environment in a relatively short period of time. In descending at a speed of from 400 to 500 miles per hour the period of descent is a matter of seconds and the change in environment is almost instantaneous. While clothing and a supply of oxygen buffer the effect of the change in temperature and density, and hence assume a critical importance in the performance of the fighting unit, neither buffer the effect of change of absolute pressure on the body itself.

In order to simulate the environmental conditions of military flight and combat, it is necessary to build, at the University's College of Medicine, a low-range, air- and pressure-conditioned room, and a high-range, air- and pressure-conditioned chamber. The need for both a room and a chamber was decided upon after taking into consideration the use to be made of the equipment and the operating costs, both during the war and after the war, and the capital costs.

In addition to researches involving anoxia, temperature, pressure, clothing, and acceleration, consideration should be given to studies for improvement of vision, particularly at night, and for the alleviation of physical and mental fatigue.

#### **b. Submarine Medicine**

Modern submarine warfare involves greater operating depths, longer period of submergence, and greater fear stresses than in any previous war. Apparatus designed for research in submarine medicine must include a sizable steel chamber with proper locks, and escape hatches which will afford, with an adequate factor of safety, positive pressures of the order of 230 lb. per sq. in. (equivalent to 500 feet depth of sea water). The chamber should also be capable of withstanding negative absolute pressures of the order of 2.132 in. Hg. or 1.05 lb. per sq. in. at a temperature of minus 70° F. (the absolute pressure and the temperature at an altitude of 60,000 ft.). The facilities for control of air pressure and air temperatures over a large range of values are necessary in order to do any research work of this type.

#### **c. Climatic Medicine**

Foot and mobile troops are in action from the Arctic to the Tropics, under environmental conditions far different from those of their natural abode. In the Arctic they are subjected to extreme cold, continuous winds, unaccustomed food, and a dearth of sunshine. In the Tropics they are subjected to excessive heat, intense solar radiation, unaccustomed food, and tropical diseases. Scientific knowledge of the effect of clothing, food, shelter, and medical attention for each environmental condition is of utmost importance in maintaining the health and fighting efficiency of the men, and a large amount of research facilities and personnel is required to obtain this information as quickly as possible.

Present knowledge of the physiological response of humans to atmospheric environment indicates the possibility of developing a method or methods of classification which would permit a segregation of troops in accordance with their ability to withstand extremes of cold and heat and other atmospheric conditions associated with their duties and scene of operations. Likewise, tests which will permit the classification of individuals in accordance with their ability to withstand unusual mental and physical stresses that are peculiar to certain specialized branches of the service are needed.

For the simulation of extreme conditions of temperature and humidity on a number of subjects at a time it is necessary to build and equip four- and seven-bed environmental-controlled rooms. These rooms will be of utmost importance in the research and educational program after the war.

## Railway and Highway Research Projects and Publications of the Engineering Experiment Station

Since the organization of the Engineering Experiment Station in 1903 many important contributions have been made to promote the safety, convenience and the economy of railway and highway transportation. The researches were made possible by the availability of an excellent materials testing laboratory, a locomotive laboratory, a brake shoe and car wheel laboratory, test cars for steam and electric railways, and most important, by providing a competent staff. The proposed airport and laboratories, and the establishment of a new educational and research program, will make possible contributions to air transportation comparable to those which have been made to railway and highway transportation.

Many investigations have been financed by railway and highway associations, by manufacturers of equipment and supplies, by technical societies, and by governmental agencies. The following list of such cooperative research projects is arranged in chronological order:

### Research Projects

- STRESSES IN RAILROAD TRACK, in cooperation with the American Railway Engineering Association and the American Society of Civil Engineers (1914 to 1941).
- CHILLED IRON CAR WHEELS, in cooperation with the Association of Manufacturers of Chilled Car Wheels (1915-1921).
- ILLINOIS COAL IN LOCOMOTIVE SERVICE, in cooperation with the International Railway Fuel Association and U. S. Bureau of Mines (1915-1916).
- VENTILATION OF HUDSON RIVER VEHICULAR TUNNEL, in cooperation with the New York State Bridge and Tunnel Commission and New Jersey Interstate Bridge and Tunnel Commission (1922).
- DRAINAGE INVESTIGATION, in cooperation with U. S. Bureau of Public Roads (1924).
- BOILER FEED WATER TREATMENT, in cooperation with the Utilities Research Commission, Inc. (1924-1927).
- IMPACT IN STEEL STRUCTURES, in cooperation with the Utilities Research Commission, Inc. (1924-1931).
- LARGE ROLLERS, in cooperation with the Scherzer Rolling Lift Bridge Company, the American Railway Association, and the American Railway Engineering Association (1926-1930).
- FATIGUE FAILURE OF CAR AXLES, in cooperation with the Utilities Research Commission, Inc. (1926-1931).
- RIVETED CONNECTIONS, in cooperation with the Chicago Bridge and Iron Works (1928-1930).
- FISSURES IN STEEL RAILS, in cooperation with the Utilities Research Commission, Inc. (1928-1932).
- PERFORMANCE OF STEAM LOCOMOTIVE EQUIPPED WITH NICHOLSON THERMIC SYPHON, in cooperation with the Illinois Central Railroad and the Locomotive Firebox Company (1930).
- SOLUBILITY STUDIES OF BOILER WATERS, in cooperation with the Utilities Research Commission, Inc. (1930- ).

- REINFORCED CONCRETE ARCHES, in cooperation with the U. S. Bureau of Public Roads, the American Society of Civil Engineers, and the Engineering Foundation (1930-1935).
- FRICTIONAL QUALITIES OF RAILWAY BRAKE SHOES, in cooperation with the Manufacturers of Steel Car Wheels (1931-1933).
- RAILS INVESTIGATION, in cooperation with the Association of American Railroads and the Rail Manufacturers Technical Committee (1931- ).
- SCALE STUDIES, in cooperation with the National Aluminate Corporation (1933-1936).
- STRENGTH OF CHILLED CAR WHEELS, in cooperation with the Association of Manufacturers of Chilled Car Wheels (1934-1937).
- RESISTANCE OF THE TREADS OF CHILLED CAR WHEELS TO HEAT CHECKING, in cooperation with the Association of Manufacturers of Chilled Car Wheels (1934-1937).
- STEEL COLUMNS, in cooperation with the New York, Chicago, and St. Louis Railroad Company (1934-1936).
- REVERSED STRESSES ON RIVETED CONNECTIONS, in cooperation with the State of California (1934-1939).
- REINFORCED CONCRETE SLABS, in cooperation with the U. S. Public Roads Administration and the Illinois State Division of Highways (1936- ).
- THE SOUNDNESS OF CHICAGO REGION DOLOMITES, in cooperation with the Illinois State Geological Survey Division, the Illinois Division of Highways and the Department of Public Works and Buildings (1936- ).
- CONTINUOUS WELDED RAIL, in cooperation with the American Association of Railroads (1937- ).
- FATIGUE STRENGTH OF WELDED JOINTS FOR STRUCTURAL STEEL MEMBERS, in cooperation with the U. S. Public Roads Administration (1938- ).
- STEEL CAR WHEELS, in cooperation with the Carnegie-Illinois Steel Corporation (1938-1941).
- STEEL CAR WHEELS, in cooperation with the Technical Board of the Wrought Steel Wheel Industry (1941- ).
- STEEL BRAKE SHOES, in cooperation with the Tennessee Coal, Iron and Railroad Company (1939- ).
- EXPANSION JOINTS IN PAVEMENTS, in cooperation with the State of Illinois, Department of Public Works and Buildings, Division of Highways (1937- ).
- EARTH PRESSURE ON RIGID CULVERTS, in cooperation with the State of Illinois, Department of Public Works and Buildings, Division of Highways (1940- ).
- ENDURANCE OF CHILLED IRON CAR WHEELS UNDER CONTINUED BRAKE APPLICATION, in cooperation with the Griffin Wheel Company (1940- ).
- HIGH STRENGTH LOW-ALLOY PLATES AND RIVETS, in cooperation with the American Bridge Company (1940- ).

In addition to cooperative research projects on railway and highway problems is one on aeronautical problems:

- LOAD RESISTING PROPERTIES OF PLASTICS FOR AIRPLANE PARTS AND FATIGUE PROPERTIES OF ALUMINUM ALLOYS FOR AIRPLANE PROPELLERS, in cooperation with the National Advisory Committee for Aeronautics (1940- ).

### Publications

Six formal reports on the investigation of Stresses in Railroad Track were prepared by Professor Arthur N. Talbot and published in more than 1200 pages of the PROCEEDINGS of the American Railway Engineering Association and in part also in the TRANSACTIONS of the American Society of Civil Engineers. The investigation was conducted to obtain information on the properties, mode of action, and resistances developed in the various parts of the track structure (rails, ties, ballast, and roadbed) under locomotives and cars moving at various speeds. Tests were made with various types of locomotives and cars on the track of more than twenty railroads in various parts of the country, and experimental work was carried on in the laboratory. The reports on the results of this investigation have been characterized as one of the most significant contributions to the scientific knowledge of railroads ever made. The results of other investigations of interest to railway and highway transportation have been recorded in the following publications of the Engineering Experiment Station:

- BULLETIN 5. Resistance of Tubes to Collapse, by A. P. Carman and M. L. Carr. 1906.
- BULLETIN 6. Holding Power of Railroad Spikes, by R. L. Webber. 1906.
- BULLETIN 11. The Effect of Scale on the Transmission of Heat Through Locomotive Boiler Tubes, by E. C. Schmidt and J. M. Snodgrass. 1907.
- BULLETIN 17. The Weathering of Coal, by S. W. Parr, N. D. Hamilton, and W. F. Wheeler. 1907.
- BULLETIN 22. Tests of Cast-Iron and Reinforced Concrete Culvert Pipe, by A. N. Talbot. 1908.
- BULLETIN 26. High Steam Pressure in Locomotive Service, by W. F. M. Goss. 1908.
- BULLETIN 32. The Occluded Gases in Coal, by S. W. Parr and P. Barker. 1909.
- BULLETIN 37. Unit Coal and the Composition of Coal Ash, by S. W. Parr and W. F. Wheeler. 1909.
- BULLETIN 38. The Weathering of Coal, by S. W. Parr and W. F. Wheeler. 1909.
- BULLETIN 41. Tests of Timber Beams, by A. N. Talbot. 1909.
- BULLETIN 43. Freight Train Resistance, by E. C. Schmidt. 1910. Reprinted in condensed form, 1934.
- BULLETIN 46. The Spontaneous Combustion of Coal, by S. W. Parr and F. W. Kressman. 1910.
- BULLETIN 48. Resistance to Flow through Locomotive Water Columns, by A. N. Talbot and M. L. Enger. 1911.
- BULLETIN 49. Tests of Nickel-Steel Riveted Joints, by A. N. Talbot and H. F. Moore. 1911.
- BULLETIN 57. Superheated Steam in Locomotive Service, by W. F. M. Goss. 1912.
- BULLETIN 59. The Effect of Cold Weather on Train Resistance and Tonnage Rating, by E. C. Schmidt and F. W. Marquis. 1912.
- BULLETIN 65. The Steam Consumption of Locomotive Engines from Indicator Diagrams, by J. P. Clayton. 1913.
- BULLETIN 74. The Tractive Resistance of a 28-Ton Electric Car, by H. H. Dunn. 1914.
- BULLETIN 82. Laboratory Test of a Consolidation Locomotive, by E. C. Schmidt, J. M. Snodgrass, and R. B. Keller. 1915.

- BULLETIN 90. Some Graphical Solutions of Electric Railway Problems, by A. M. Buck. 1916.
- BULLETIN 92. The Tractive Resistance on Curves of a 28-Ton Electric Car, by E. C. Schmidt and H. H. Dunn. 1916.
- BULLETIN 94. The Embrittling Action of Sodium Hydroxide on Soft Steel, by S. W. Parr. 1917.
- BULLETIN 97. Effects of Storage upon the Properties of Coal, by S. W. Parr. 1917.
- BULLETIN 101. Comparative Tests of Six Sizes of Illinois Coal on a Mikado Locomotive, by E. C. Schmidt, J. M. Snodgrass, and O. S. Beyer, Jr. 1917.
- BULLETIN 110. Passenger Train Resistance, by E. C. Schmidt and H. H. Dunn. 1918.
- BULLETIN 116. Bituminous Coal Storage Practice, by H. H. Stoek, C. W. Hippard, and W. D. Langtry. 1920.
- BULLETIN 129. An Investigation of the Properties of Chilled Iron Car Wheels, Part I, Wheel Fit and Static Load Strains, by J. M. Snodgrass and F. H. Guldner. 1922.
- BULLETIN 134. An Investigation of the Properties of Chilled Iron Car Wheels, Part II, Wheel Fit, Static Load, and Flange Pressure Strains; Ultimate Strength of Flange, by J. M. Snodgrass and F. H. Guldner. 1922.
- BULLETIN 135. An Investigation of the Properties of Chilled Iron Car Wheels, Part III, Strains Due to Brake Application; Coefficient of Friction and Brake-Shoe Wear, by J. M. Snodgrass and F. H. Guldner. 1923.
- BULLETIN 155. The Cause and Prevention of Embrittlement of Boiler Plate, by S. W. Parr and F. G. Straub. 1926.
- BULLETIN 162. Tests on the Bearing Value of Large Rollers, by W. M. Wilson. 1927.
- BULLETIN 165. A Study of Fatigue Cracks in Car Axles, by H. F. Moore. 1927.
- BULLETIN 167. Freight Train Curve Resistance on a One Degree Curve and on a Three Degree Curve, by E. C. Schmidt. 1927.
- BULLETIN 168. Heat Transmission Through Boiler Tubes, by H. O. Croft. 1927.
- BULLETIN 177. Embrittlement of Boiler Plate, by S. W. Parr and F. G. Straub. 1928.
- BULLETIN 180. The Classification of Coal, by S. W. Parr. 1928.
- BULLETIN 191. Rolling Tests on Plates, by W. M. Wilson. 1929.
- BULLETIN 197. A Study of Fatigue Cracks in Car Axles, Part II, by H. F. Moore, S. W. Lyon and N. J. Alleman. 1929.
- BULLETIN 212. Stresses Due to the Pressure of One Elastic Solid Upon Another, by H. R. Thomas and V. A. Hoersch. 1930.
- BULLETIN 216. Embrittlement of Boilers, by F. G. Straub. 1930. Reprinted 1933.
- BULLETIN 220. Tests of a Mikado-Type Locomotive Equipped with Nicholson Thermic Syphons, by E. C. Schmidt, E. G. Young, and H. J. Schrader. 1930.
- BULLETIN 226. Laboratory Tests of Reinforced Concrete Arches with Decks, by W. M. Wilson. 1931.
- BULLETIN 232. Runoff Investigations in Central Illinois, by G. W. Pickels. 1931.
- BULLETIN 234. Movement of Piers During Construction of Multiple Span Reinforced Concrete Arch Bridges, by W. M. Wilson. 1931.
- BULLETIN 244. A Study of Stresses in Car Axles under Service Conditions, by H. F. Moore, N. H. Roy, and B. B. Betty. 1932.

- BULLETIN 256. A Study of Locomotive Front End, Including Tests of a Front-End Model, by E. G. Young. 1933.
- BULLETIN 257. The Friction of Railway Brake Shoes, Its Variation with Speed, Shoe Pressure and Wheel Material, by E. C. Schmidt and H. J. Schrader. 1933.
- BULLETIN 261. The Cause and Prevention of Calcium Sulphate Scale in Steam Boilers, by F. G. Straub. 1933.
- BULLETIN 263. The Bearing Value of Rollers, by W. M. Wilson. 1934.
- BULLETIN 269. Laboratory Tests of Three-Span Reinforced Concrete Arch Ribs on Slender Piers, by W. M. Wilson and R. W. Kluge. 1934.
- BULLETIN 270. Laboratory Tests of Three-Span Reinforced Concrete Arch Bridges with Decks on Slender Piers, by W. M. Wilson and R. W. Kluge. 1934.
- BULLETIN 274. A Supplementary Study of the Locomotive Front End by Means of Tests on a Front End Model, by E. G. Young. 1935.
- BULLETIN 280. The Effect of Residual Longitudinal Stresses upon the Load Carrying Capacity of Steel Columns, by W. M. Wilson and R. L. Brown. 1935.
- BULLETIN 283. A Study of the Reactions of Various Inorganic and Organic Salts in Preventing Scale in Steam Boilers, by F. G. Straub. 1936.
- BULLETIN 294. Tests of Strength Properties of Chilled Car Wheels, by F. E. Richart, R. L. Brown, and P. G. Jones. 1937.
- BULLETIN 298. Resistance to Heat Checking of Chilled Iron Car Wheels and Strains Developed Under Long-Continued Application of Brake Shoes, by E. C. Schmidt and H. J. Schrader. 1937.
- BULLETIN 301. The Friction of Railway Brake Shoes at High Speed and High Pressure, by H. J. Schrader. 1938.
- BULLETIN 302. Fatigue Tests of Riveted Joints, by W. M. Wilson and F. P. Thomas. 1938.
- BULLETIN 303. Solutions for Certain Rectangular Slabs Continuous over Flexible Supports, by V. P. Jensen. 1938.
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- BULLETIN 310. Fatigue Tests of Butt Welds in Structural Steel Plates, by W. M. Wilson and A. B. Wilder. 1938.
- BULLETIN 312. An Investigation of Wrought Steel Railway Car Wheels: Part I, Tests of Strength Properties of Wrought Steel Car Wheels, by T. J. Dolan and R. L. Brown. 1939.
- BULLETIN 314. Tests of Reinforced Concrete Slabs Subjected to Concentrated Loads, by F. E. Richart and R. W. Kluge. 1939.
- BULLETIN 315. Moments in Simple Span Bridge Slabs with Stiffened Edges, by V. P. Jensen. 1939.
- BULLETIN 317. Fatigue Strength of Connection Angles, by W. M. Wilson and J. V. Coombe. 1939.

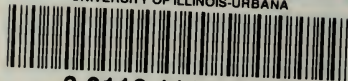
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- BULLETIN 332. Analyses of Skew Slabs, by V. P. Jensen. 1941.
- CIRCULAR 6. The Storage of Bituminous Coal, by H. H. Stock. 1918.
- CIRCULAR 8. The Economical Use of Coal in Railway Locomotives. 1918.
- CIRCULAR 10. The Grading of Earth Roads, by W. M. Wilson. 1923.
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- CIRCULAR 18. The Construction, Rehabilitation and Maintenance of Gravel Roads Suitable for Moderate Traffic, by C. C. Wiley. 1929.
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- REPRINT 13. First Progress Report of the Joint Investigation of Continuous Welded Rail, by H. F. Moore. 1939.
- REPRINT 17. Second Progress Report of the Joint Investigation of Continuous Welded Rail, by H. F. Moore, H. R. Thomas, and R. E. Cramer. 1940.







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